

# DECADAL CHANGES IN SNOW COVER CHARACTERISTICS IN SLOVAKIA OVER THE PERIOD 1921 – 2020



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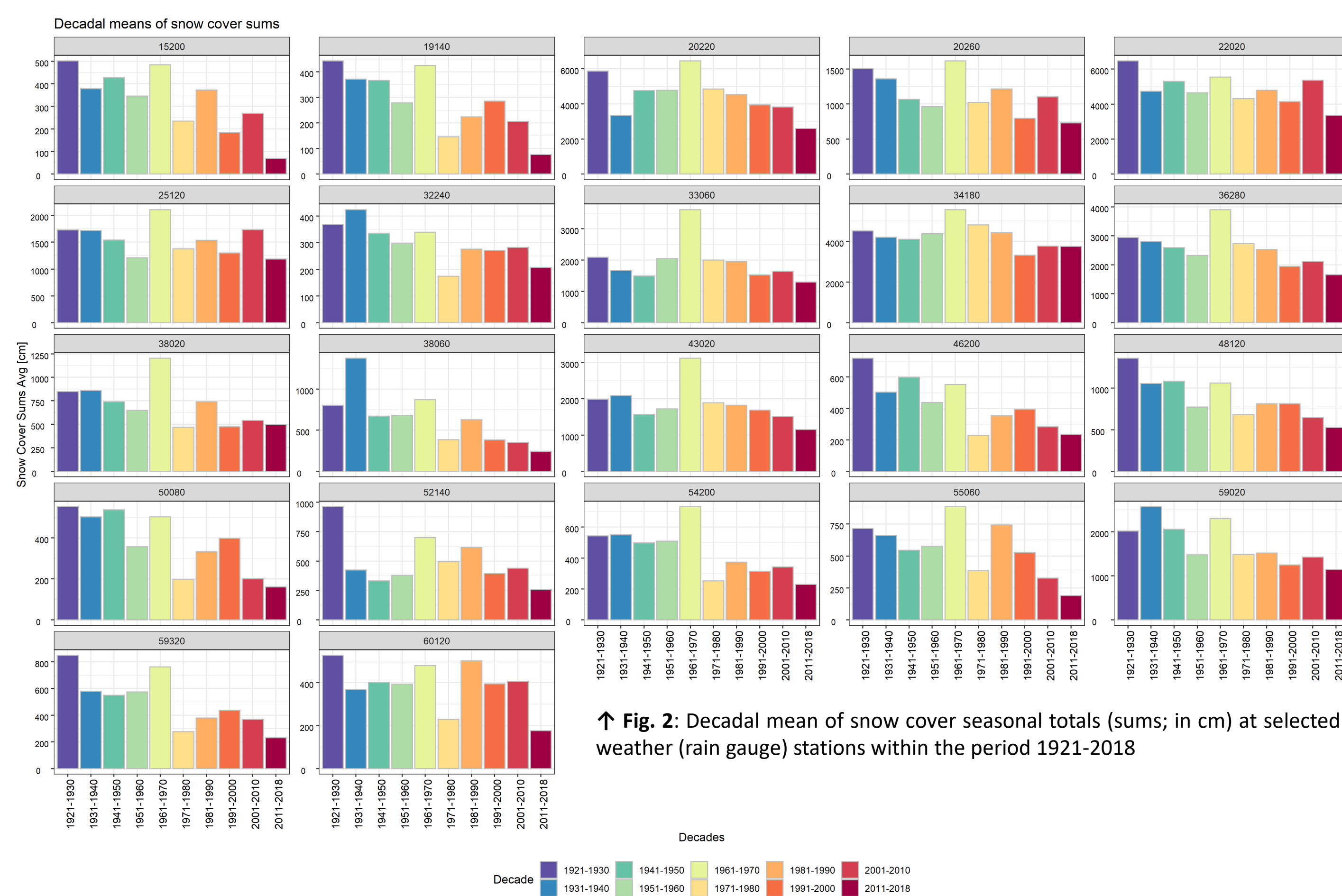
## ABSTRACT

Long-term changes in air temperature regime have significant consequences for the atmospheric precipitation regime in Slovakia. Moreover, the combination of air temperature increase, changes in annual precipitation regime, as well as increasing proportion of liquid and mixed precipitation on its annual total, have had a profound effect on the snow cover occurrence.

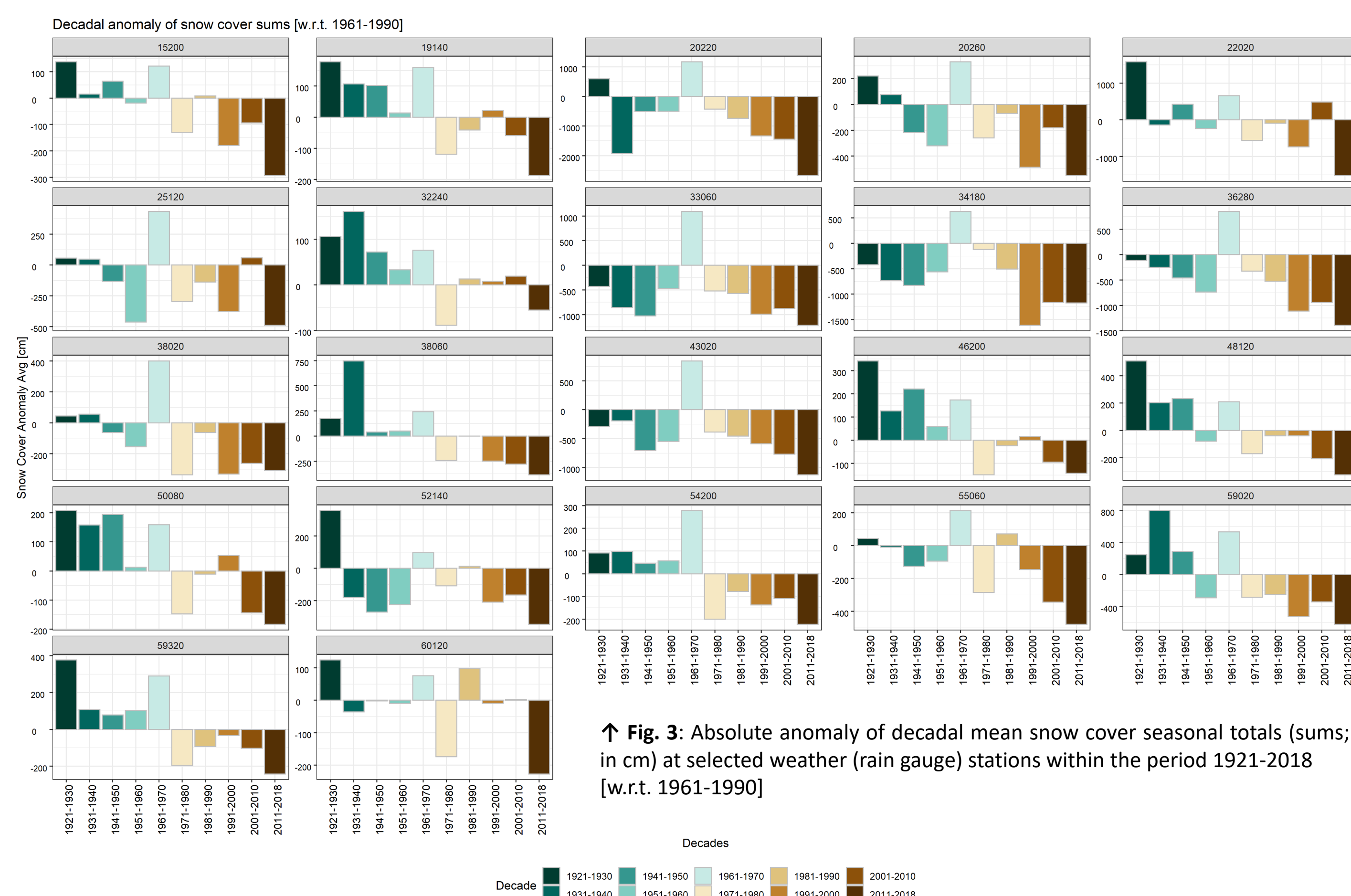
In majority of territory of Slovakia, with the exception of high altitudes, the stability of snow cover incidence has decreased. In the last decade of the 20th century and in the first two decades of the 21st century, there was a significant increase in mean values of the air temperature characteristics in every individual decade over the period. Very clear decline of amount of snow cover in Slovakia was recorded especially in the second decade of the 21st century however significant regional differences of measurable long-term trends have been affected by very complex natural conditions of Slovakia.

The paper we analyze selected snow cover characteristics, such as the sum of snow in the decadal time scale for the period 1921 – 2018 (1921/22-2017/18). The analysis is performed using the time series of daily values of snow cover at selected weather stations in different regions of Slovakia.

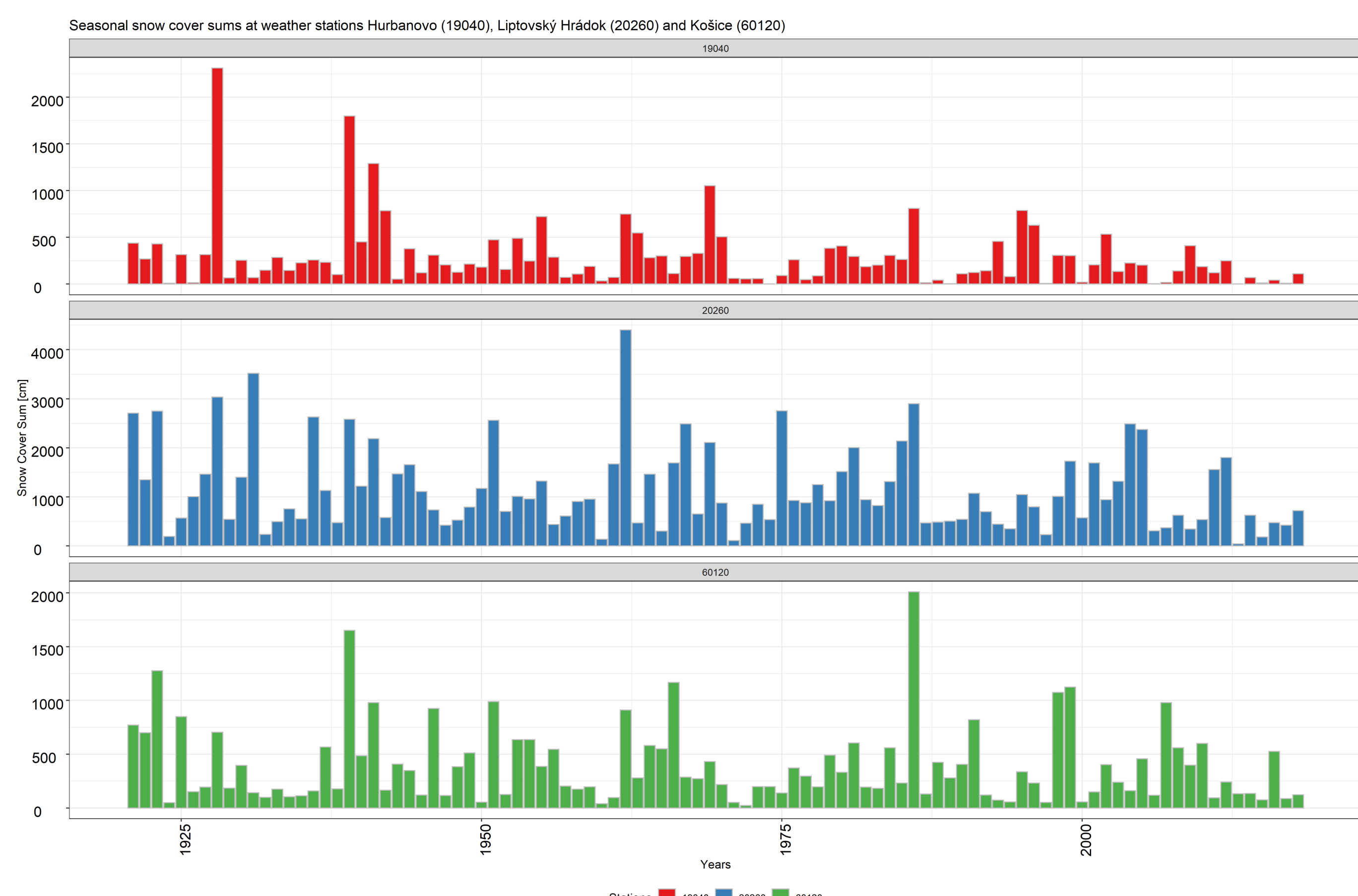
## SNOW COVER DECADAL CHANGES



↑ Fig. 2: Decadal mean of snow cover seasonal totals (sums; in cm) at selected weather (rain gauge) stations within the period 1921-2018

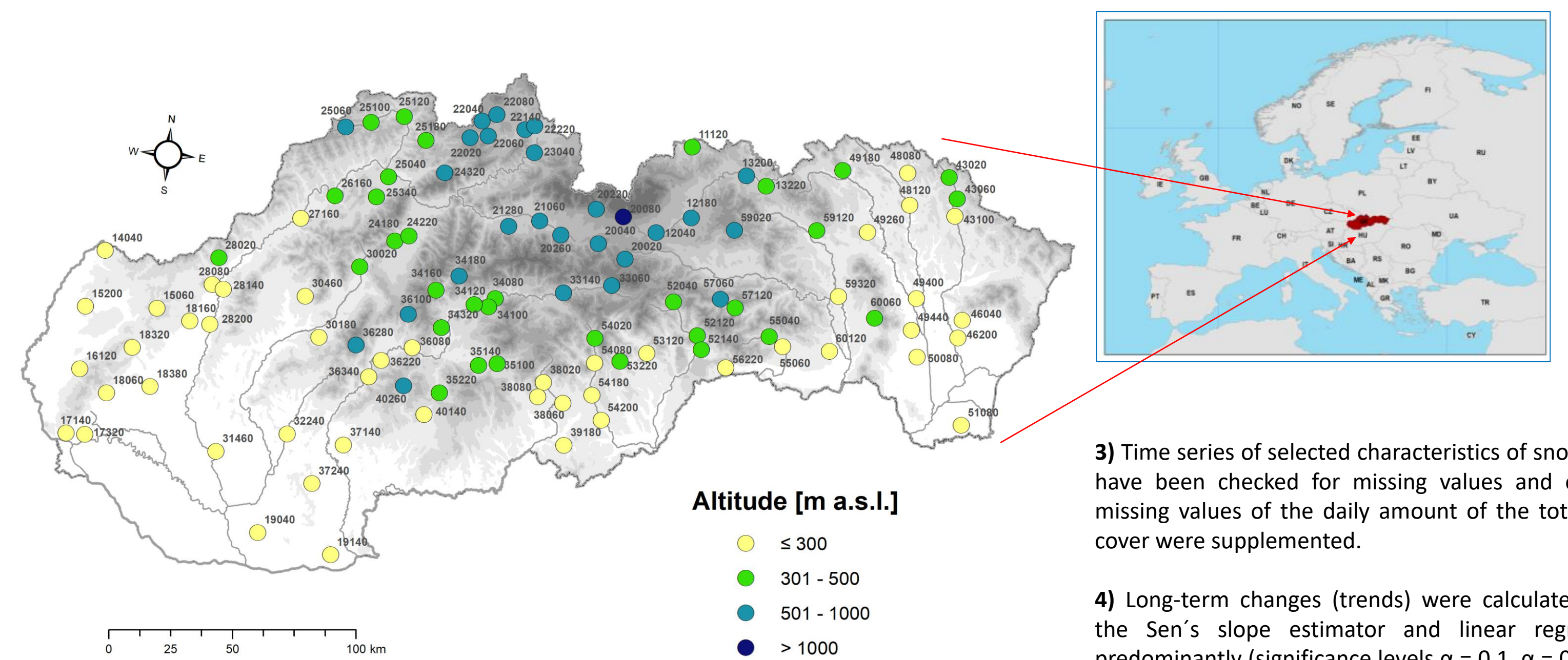


↑ Fig. 3: Absolute anomaly of decadal mean snow cover seasonal totals (sums; in cm) at selected weather (rain gauge) stations within the period 1921-2018 [w.r.t. 1961-1990]



↑ Fig. 4: Long-term changes in seasonal snow cover totals (sums, in cm) at weather stations Hurbanovo (19040), Liptovský Hrádok (20260) and Košice (airport) within the period 1921/22 – 2017/2018.

## MATERIAL AND METHODS



↑ Fig. 1: Spatial distribution of rain gauge stations within the territory of Slovakia (classified by its altitude)

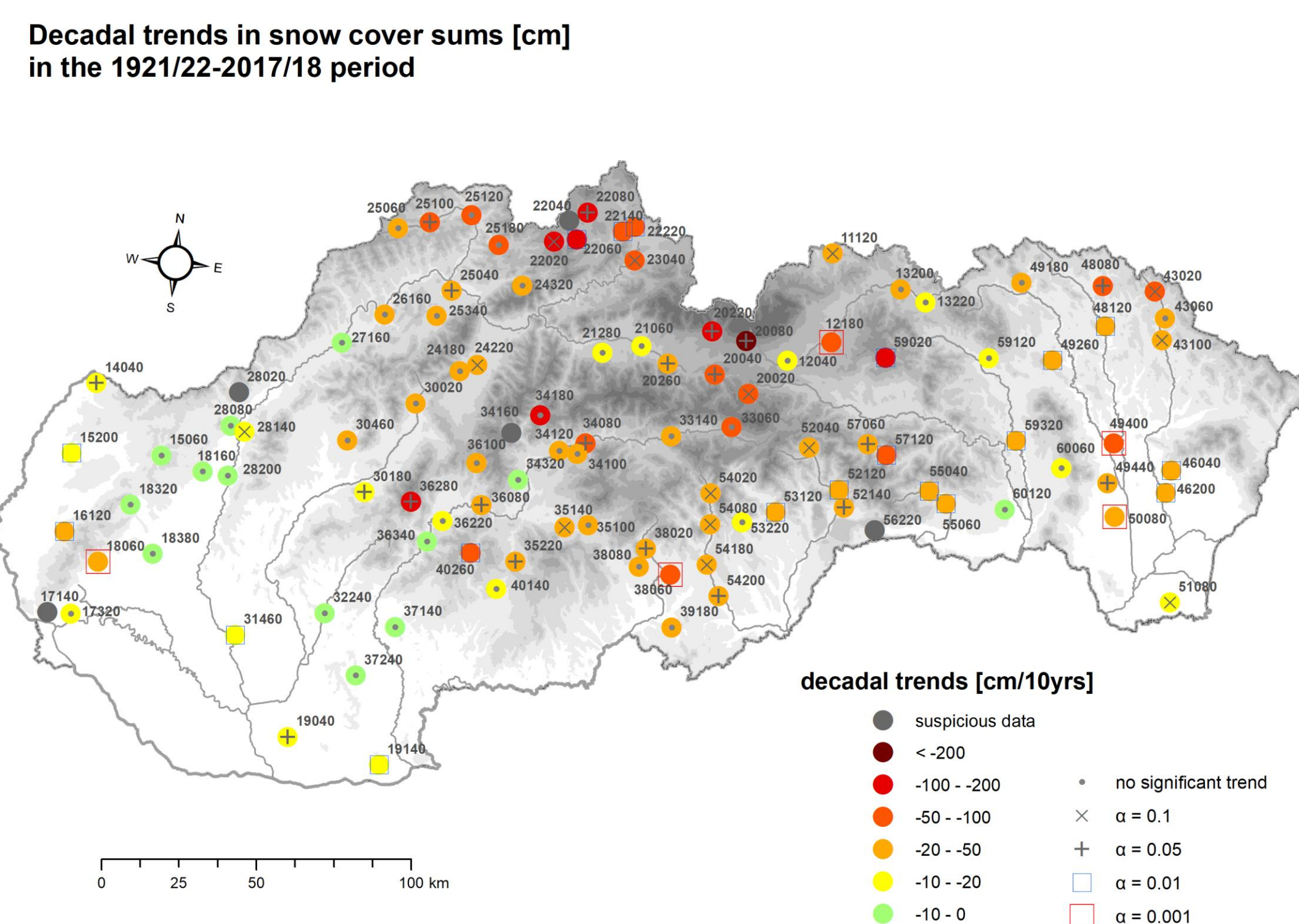
- 1) In the contribution the analysis of spatial and temporal long-term changes and trend in time-series of total snow cover characteristics is presented.
- 2) Seasonal (July – June) sums of total snow cover have been calculated for 107 weather stations covering the winter seasons starting 1921/1922 and ending 2017/2018.

3) Time series of selected characteristics of snow cover have been checked for missing values and outliers; missing values of the daily amount of the total snow cover were supplemented.

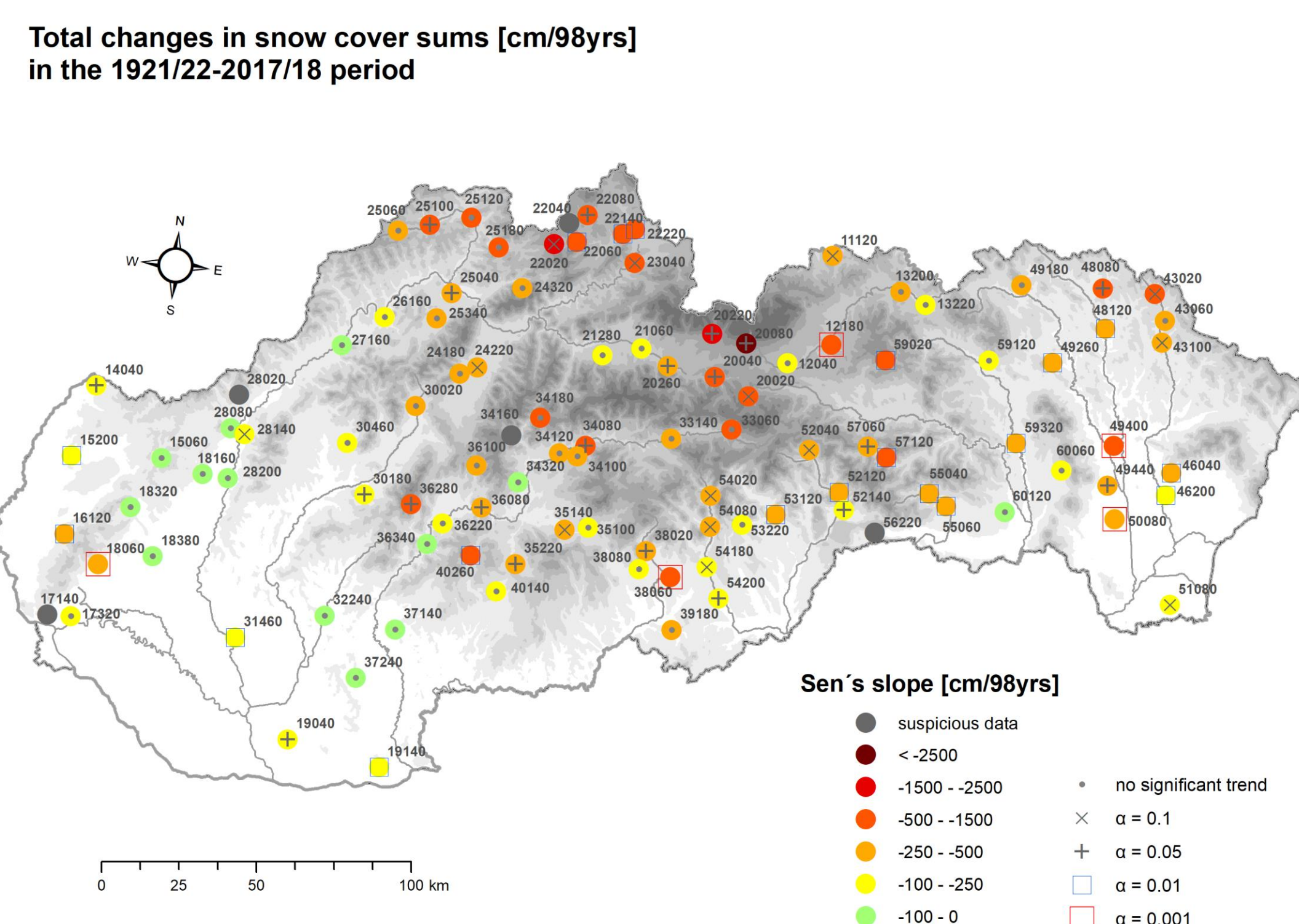
4) Long-term changes (trends) were calculated using the Sen's slope estimator and linear regressions predominantly (significance levels  $\alpha = 0.1$ ,  $\alpha = 0.05$ ,  $\alpha = 0.01$  and  $\alpha = 0.001$  were tested with Mann-Kendall test).

5) Some suspicious time series were detected at weather stations with ID 17140, 28020, 22040, 36100 and 56220 - in these cases, significant temporal inhomogeneities predominantly caused by the relocation of the meteorological station were identified (stations were finally excluded from the analysis).

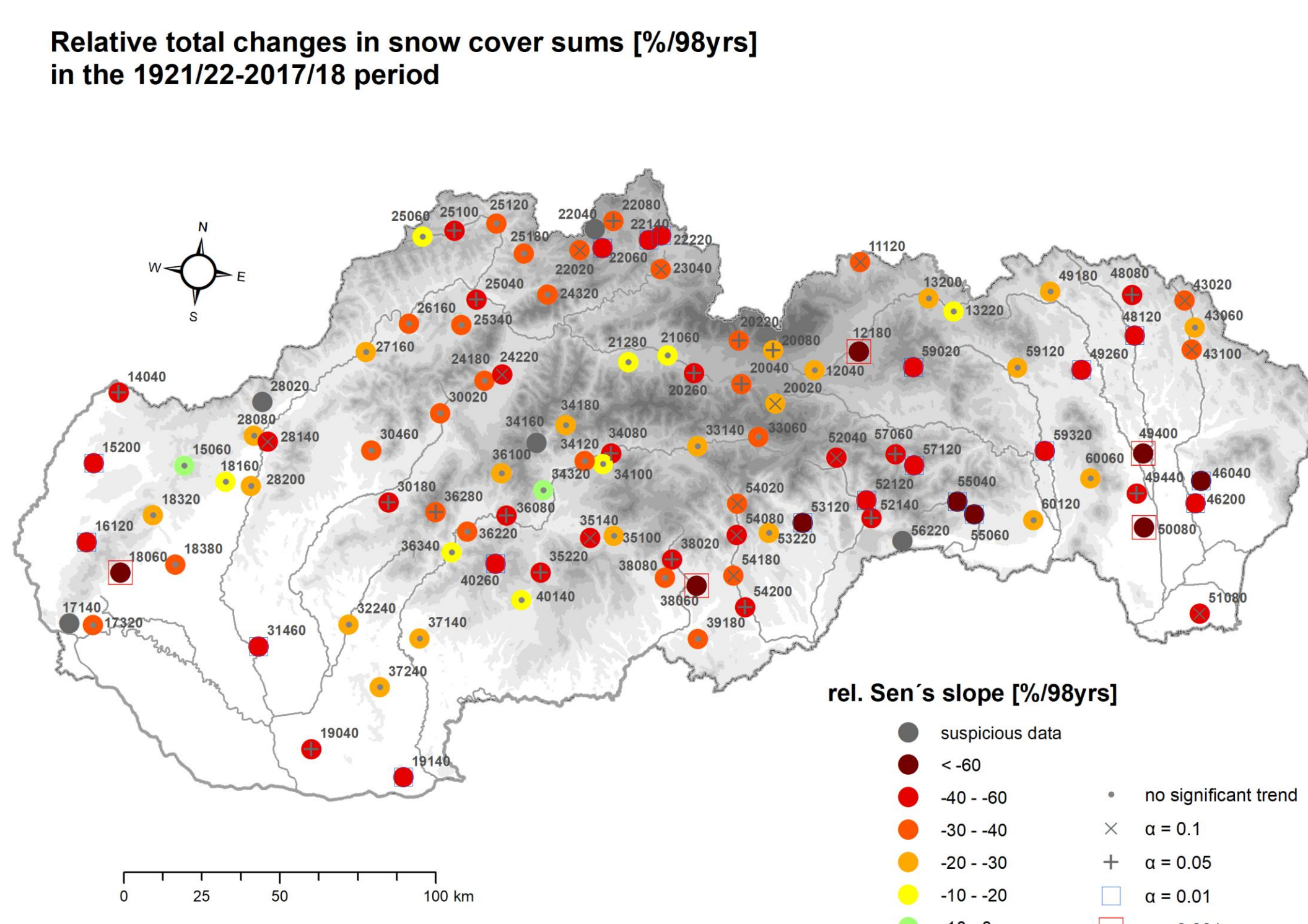
## SNOW COVER TRENDS



← Fig. 5: Decadal changes (trends; per 10yrs) in snow cover sums in cm/10yrs at selected weather stations in Slovakia calculated using Sen's slope estimator within the period 1921-2018 (at significance level  $\alpha = 0.1$ ,  $\alpha = 0.05$ ,  $\alpha = 0.01$  and  $\alpha = 0.001$  and tested with Mann-Kendall test; suspicious time series are depicted)



← Fig. 6: [Absolute] Overall changes in snow cover sums in cm/98yrs at selected weather stations in Slovakia calculated using Sen's slope estimator within the period 1921-2018 (at significance level  $\alpha = 0.1$ ,  $\alpha = 0.05$ ,  $\alpha = 0.01$  and  $\alpha = 0.001$  and tested with Mann-Kendall test; suspicious time series are depicted)



← Fig. 7: [Relative] Overall changes in snow cover sums in %/98yrs at selected weather stations in Slovakia calculated using Sen's slope estimator within the period 1921-2018 (at significance level  $\alpha = 0.1$ ,  $\alpha = 0.05$ ,  $\alpha = 0.01$  and  $\alpha = 0.001$  and tested with Mann-Kendall test; suspicious time series are depicted)

## CONCLUSIONS

- 1) Results indicate (mostly) statistically significant decrease in snow cover totals during the second decade of the 21st century in most of regions of Slovakia, however during the 60s (1961-1970) there were some winter seasons with abundance of snow. There have been a few very cold winters in this decade (60s), and some winters have been rich in atmospheric precipitation.
- 2) It is also noteworthy that, in contrast to the air temperature characteristics, which affected significant upward trends in the last decade of the 20th century, such clear changes in snow cover were not recorded in the analyzed snow cover time series even in the last decade of the 20th century, and not even in the first decade of the 21st century, but they finally manifested themselves during the second decade of the 21st century.
- 3) In the natural conditions of Slovakia, these trends are not confirmed in high mountain locations, where higher precipitation in winter still supports the stable occurrence of snow cover and its accumulation. From these altitudes, however, we do not have comparatively long time series of values of the total snow cover as processed in this paper. Some of the analyzed time series did not even meet the basic criteria of homogeneity, therefore their data did not become the content of the presented results.